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ABSTRACT

Readiness skills of 1,261 kindergarten students were assessed with the use of the Kindergarten Instructional Design System (KIDS). The profile provides assessment in five areas: Motor, Visual, Auditory, Language, and Conceptual. Two statistical techniques were utilized to examine the underlying structure of the measure: factor analysis and multidimensional scaling. Hypotheses focused on confirmation of the factor analytic solution by the multidimensional scaling solution. Currently, multidimensional techniques are suggested for comfirmatory use with variables because the linearity restraints of factor analysis are seen as artificially confining to variables possessing a high degree of inter-relatedness. Both perspectives can provide useful information in attempting to discern the structure of a measure. Consequently, the new KIDS assessment measure provided an excellent opportunity to apply both techniques and compare the solutions. The information was judged in reference to ease in interpretation, as well as the amount of information provided by each technique. Some statement as to their similarity is proposed, and when confirmed, is seen as validation of the underlying structure. (Author/BW)

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A COMPARISON OF FACTOR ANALYSIS AND MULTIDIMENSIONAL SCALING IN DETERMINING UNDERLYING STRUCTURE

by

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Abstract

Readiness skills of 1,261 kindergarten students were assessed with the use of the Kindergarten Instructional Design System (KIDS) provided by Title IVc of the Elementary and Secondary Act (ESEA). The profile provides assessment in five areas: a) Motor, b) Visual, c) Auditory, d) Language, and e) Conceptual. The assessment was a gross screening device, as opposed to a normed test, designed to measure skills achieved through developmental growth. The scores were viewed as indicating readiness development only.

Two statistical techniques were utilized to examine the underlying structure of the measure. Factor analysis was chosen as the traditional manner for determining structure. The use of a multidimensional scaling technique was chosen to provide an alternate solution. The two methods and their results were compared. Hypotheses focused on confirmation of the factor analytic solution by the multidimensional scaling solution. Currently, multidimensional techniques are suggested for confimatory use with variables because the linearity restraints of factor analysis are seen as artificially confining to variables possessing a high degree of interrelatedness (Kruskal & Wish, 1978). Reviewing recent studies by Loo (1982), Chignell & Stacey (1981), Walkey & Green (1981), Lytton & Youngman (1980), Campbell (1980), and Revelle (1979) in which solutions derived by factor analysis and multidimensional scaling techniques were compared indicates that both perspectives provide useful information in attempting to discern

the structure of a measure. Consequently, the new KIDS assessment measure provided an excellent opportunity to apply both techniques and compare the solutions. The information would be judged in reference to ease in interpretation, as well as, the amount of information provided by each technique. Some statement as to their similarity was proposed, and when confirmed; was seen as validation of the underlying structure.

Introduction

In an attempt to improve education, many evaluators have become interested in the assessment of skills necessary to enter school and perform successfully. The delineation of these skills will aid educators in developing instructional programs which not only allow for academic success but will allow for early identification of weak requisite abilities. One method of acquiring this information lies in the administration of different types of assessment tests. Advantages of well-known measures include: a) their reliability, b) their validity, c) their standard procedures, and d) their norms which provide accurate comparisons and generalizations.

Following the organization of a measure, confirmation of the structure is usually required to validate the instrument and its content. Factor analysis is a traditional method of securing a number of underlying factors from a larger number of contributing variables (Gorsuch, 1974). Familiarity with factor analytic techniques increases the frequency of its application to data. Other approaches involving the use of multidimensional scaling techniques were regarded as ambitious (Torgerson, 1965), in espousing the view that similarity measures be viewed as complements of distance measures in representing data in a spatial configuration. It was further stated (Torgerson, 1965) that the new procedures offered a lot, yet their limitations had to be acknowledged (loss of metric information) and further study would strengthen their application and their interpretive usefulness.

Young (1970) stated that metric determinancy of multidimensional scaling was a function of the number of points scaled, the true dimensionality of

the data, and the amount of error in the data. Comparison of the traditional factor analytic solution derived on a set of data (as a standard) to the solution provided by a multidimensional scaling technique could allow inferences as to which best represents or confirms the structure of the data. Chan & Jackson (1979) established inferential relationships by the use of a multidimensional scaling technique in their work with psychopathological traits. Their results were compared to the empirical structure obtained by factor analyzing the scales. The multidimensional scaling solution and the factor analytic solution were taken as confirmatory evidence in regard to their hypotheses concerning implicit theory and psychopathological traits. Revelle (1979) compared exploratory factor analysis with exploratory cluster analysis (a multidimensional scaling technique) and stated that hierarchical clustering algorithms may be more useful in reference to forming scales than the traditional factor analytic techniques. This was stated in reference to the item pool during construction and the necessity of it being large rather than small. Campbell (1980) found substantial correspondence between the factor analytic and cluster solutions obtained on the ratings of 19 personality theories.

Chignell & Stacey (1981) found further validation of the feasibility of multidimensional scaling techniques while using cluster analysis to determine the classification schemes for various diagnostic groups of patients. Chignell felt additional information was revealed through the use of the technique that could have been overlooked if reliance were limited to the conventional methods of component analysis and discriminant function analysis. Lytton & Youngman (1980) also utilized cluster analysis and discriminant function

analysis with their data and felt the results of the two techniques represented similar distinctions between singles and twins in reference to their expression of obedience and disobedience.

Walkey & Green (1981) successfully compared a simple nonmetric analysis of the Eysenck Personality Inventory (EPI) to a principal components analysis of the instrument as well as some higher order factor analyses. Their results indicated little additional information is gained through the complexities of higher order analyses. Loo (1982) applied cluster analyses to determine meaning from small dissimilarities among test items. Loo then applied factor analysis to determine the individual difference dimensions underlying test performance. The study suggests that complementary information may be derived if varying techniques are applied while attempting to determine the structure of data. Koch (1983) addressed the issue of applying nonmetric multidimensional scaling techniques to dichotomous test data in a paper delivered to the American Educational Research Association at the Annual Meeting in Montreal, Canada. The application, although not clearly successful, adequately demonstrates the increasing acceptance of multidimensional scaling as an alternate or complementary method. As a complementary method it would be useful while attempting to determine the underlying structure of a new measure. As the KIDS assessment profile is a new measure, it was considered advantageous to use both methods in attempting to determine the underlying structure of the measure.

Method

A total of 36 skills were measured in the KIDS assessment. Specific instructions for each task including its objectives were covered in the KIDS Readiness Assessment Examiner Training Filmstrip. Subjects were assessed individually by the examiner using an easel-like manual which contained the stimuli for each task. Scoring was accomplished by the assignment of the ratings of 3 (indicating complete mastery -- 80% and above), 2 (indicating some mastery -- 50% to 80%), and 1 (indicating little or no mastery -- below 50%).

The following variables were assessed with the KIDS measure. Variables 1-7 were contained on the Motor Scale; variables 8-16 were contained on the Visual Scale; variables 17-23 were contained on the Auditory Scale; variables 24-30 were contained on the Language Scale; and variables 31-36 were contained on the Conceptual Scale. (Variables 16 -- Letters and 23 -- Blending were not required of the kindergarten sample. They were utilized with a first grade sample.)

1. Gross Motor (Subjects asked to hop, skip.)
2. Balance (Subjects asked to stand on one foot with eyes closed and opened.)
3. Body parts (Subjects asked to point to chin, mouth, etc.)
4. Color (Subjects asked to color the wheel of a truck.)
5. Trace (Subjects asked to trace the wheel of a truck.)
6. Copy (Subjects asked to copy three designs.)
7. Cut (Subjects asked to cut out a circular shape and to cut along a straight line.)
8. Visual same (Subjects asked to find certain objects and letters from objects which are different.)
9. Visual different (Subjects asked to indicate which object is different in the set presented.)
10. Visual closure (Subjects asked to indicate what is missing in the picture presented.)

11. Association (Subjects asked to make judgments as to which objects belong together.)
12. Memory (Subjects asked to find an object presented visually for a time and then removed.)
13. Figure Ground (Subjects asked to locate an object in a background which obstructs some detail.)
14. Categories (Subjects asked to distinguish which picture does not belong with the other three.)
15. Sequence (Subjects asked to put items in an order which comes first, which follows, and which ends the sequence.)
*16. Letters (Subjects asked to identify specific letters.)
17. Memory numbers (Subjects asked to recall a number sequence.)
18. Memory words (Subjects asked to recall a word sequence.)
19. Memory story (Subjects asked to recall details of a story.)
20. Auditory closure (Subjects asked to correctly complete a sentence fragment so it will make sense.)
21. Auditory same (Subjects asked to identify letters and words spoken as to whether they are similar or dissimilar.)
22. Rhyme (Subjects asked to supply a rhyming word to a stimulus word given by the examiner.)
*23. Blending (Subjects asked to identify specific words.)
24. Counting (Subjects asked to count to 10.)
25. Colors (Subjects asked to name colors presented.)
26. Position (Subjects asked to indicate positional adjectives such as: under, above, etc.)
27. Plurals (Subjects asked to supply the plural to the singular word presented.)
28. Alphabet (Subjects asked to recite the letters of the alphabet.)
29. Shapes (Subjects asked to identify basic shapes.)
30. Expression (Subjects asked a few simple questions.)
31. Size (Subjects distinguish same size and larger and smaller,)
32. Time (Subjects asked questions concerning activities during certain parts of the day.)
33. Comparison (Subjects asked to compare the number of objects in a set.)
34. Analogies (Subjects complete orally several analogies.)
35. Opposites (Subjects supply opposite to word presented.)
36. Numbers (Subjects asked to match the number with quantity of objects in the set.)

Subjects

The data source consisted of students enrolled in either public or private schools in the Chicago metropolitan and suburban areas. They were of varied socioeconomic status, background, and school environment. The data gathered involved 1,261 kindergarten students during the 1980-81 school year.

It is acknowledged that demographic information may need to be examined in future studies, but it is not a concern of the present study.

Administration

The assessment profile was administered by trained examiners working individually with the subjects. Another aspect inherent in this study was the utilization of some parents as examiners with knowledge gained as to their rapport and familiarity with the child and its benefit in establishing accurate assessment. Prior studies established the reliability of the rating system and the use of parents as trained examiners. This will be the focus of later studies and in no way detracts from the uniformity of the administration procedures.

Analysis

Factor analysis (PA-1; Varimax) was performed on the data using the program available in the SPSS manual (Version M, dated 1980). The polycon analysis performed was provided by the Psychometric Laboratory of the University of North Carolina (Version 2.06, dated 1974).

Discussion of Results

Factor analysis was performed on the data and initially yielded six orthogonal factors. Examination of the eigenvalues and the factors indicated a four factor solution would best summarize the data. The communalities of the variables were also examined to determine the extent to which they

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INSERT TABLE 1 HERE

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contributed to the common variance. A variable was considered an insufficient contributor to the common variance if the communality value of the variable fell below .30. The value of .30 is an arbitrary one and subjective evaluation is necessary when values are close to .30. In the present analysis four variables were shown to have communality values below .30. (Variable 12 -- Memory .29; Variable 14 -- Categories .29; Variable 15 -- Sequence .22; and Variable 17 -- Memory .22). Although these variables' communalities fell below .30, it was felt they should be retained for the analysis. The values were very close to the arbitrary value of .30 and the communalities of the other variables were very high. These variables were seen as contributing to a lesser degree than the other variables; yet an attempt was made to utilize all the variables in the analysis. The measure was seen as an integral whole and the lower communalities of a few variables were not seen as detracting from the analysis.

With the decision to include all the variables in the analysis; and to request a four factor solution for the data, the following four orthogonal factors were obtained. Varimax was chosen to maximize the variance across all factors without any expectation that the data would exhibit a general

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INSERT TABLE 2 HERE

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factor. These are the most obvious requirements, but varimax is usually chosen in initial and exploratory types of studies such as the present one.

In deciding which variables contribute significantly to which factors, thought must be given to the size of the variable's loading. The size of

significant loadings is another arbitrary area and is left to the researcher's subjective knowledge of the variables. Many authors suggest loadings of .30 and above are important contributors to a factor. Others contend that loadings must be .50 or above to be important contributors to a factor. The factors reported here are comprised of all variable loadings of .30 and above. The interpretations derived from the variables (i.e. labeling of the factors) were drawn from those variables with loadings of .50 and above.

The factors were labeled after considering the skills necessary to successfully complete the tasks asked of the subjects. The first seven variables of Factor I involve the use of visual skills. These perceptual skills are evidenced in the ability to identify objects, distances, and directions given to the subject by the examiner. Many of the variables were also the logical application of visual information received by the subject. Analogies (Variable 34) requires the identification of objects before the relational aspect can be judged. Plurals (Variable 27) necessitates the identification of single objects to which the subject supplies the plural. Time (Variable 32) requires identification of the time of the day with certain activities or events.

The variables of Rhyme (Variable 22 -.47) and Shapes (Variable 29 -.34) are seen as unusual due to their negative loadings. It was not immediately apparent as to why these two variables would demonstrate this relatedness on Factor I. It is suggested that one could account for the relatedness of these two variables by reference to studies done concerning "split brain" research. This literature maintains that both the ability

to discern shapes and to rhyme words is a function under the control of the spatial modality of the brain. The mutual control center accounts for their related nature, although in an intuitive fashion one might not expect the two variables to be highly related.

Factor II consisted of the many variables requiring the identification skill inherent in Factor I. The difference between the two factors appears to be the ability of the subject to discern a pattern and continue it or apply it to other stimuli. Opposites (Variable 35) requires the subject to recognize the pattern of giving words in opposition. Memory story (Variable 19) requires the subject to recognize the pattern of sequence while relating a story back to the examiner. The other variables in this factor require the subject to recognize some pattern of responding to the stimuli presented; and thus, successfully accomplish the task. Many of the variables on Factor II were also represented on Factor I and this was taken as confirmation of the use of identification skills for both factors. The variables of this measure clearly emphasize the use of identification skills when responding to the stimuli. The underlying component of the ability to identify stimuli and patterns could be tied to the conceptual dimension the measure proposed was part of the assessment. Early primary education emphasizes the use of identifying skills in preparing students for subsequent school work; which becomes increasingly abstract while developing concepts.

Factor III contained variables whose tasks were given auditorily while requiring the subject to demonstrate use of their memory. Colors (Variable 25) must be visually identified and the correct label supplied

by the subject from memory. The alphabet (Variable 28) is recited (auditory mode) from memory by the subject. The remaining variables, especially Variable 21 -- Auditory closure, demonstrate the same use of auditory and memory skills. The measure gains support as an auditory dimension was proposed to underlie this assessment tool. Memory is a skill acknowledged as essential in all learning theories and would be obvious in its appearance as part of the underlying structure of a measure.

Factor IV and the vairables which comprise it emphasize the subjects' ability to demonstrate fine motor skills. The ability to copy, cut, trace, and color satisfactorily is dependent on the coordination and use of small muscles. Memory (Variable 12) is a little difficult to interpret, but may come under the exercise of care in completing tasks. Variable 12 requires an object to be shown to the subject and then removed from sight. The subject is then required to locate the object in another stimulus field. Another possible interpretation can be drawn, if one considers the age of the subjects, by viewing motor skills as highly correlated to general curiosity and effectiveness in exploring the environment. It could be hypothesized that motor skills and memory would be a useful skill when locating an object in a different stimulus field. The skills on this factor support a visual element as well as a motor component. The visual and motor components confirm two of the areas proposed by the assessment.

Due to the inherent nature of the variables used in this measure, one could justify an interpretation of correlation among the skills required in some of the tasks. An oblique rotation would allow the correlated factors to produce a solution and this could be compared to the orthogonal solution. With the thought of correlated factors, an oblique rotation of the factors produced the following four factor oblique solution (PA-2 --- Direct Oblimin with default value of Delta= zero; Kim, 1978).

Although a comparison of the orthogonal solution and the oblique solution yields interesting results, they are difficult to clearly interpret. Groups of variables from Factor I in the orthogonal

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INSERT TABLE 3 HERE

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solution now become part of the Factor II in the oblique solution. This is not usually seen in factor analytic comparisons. The adjustment of the axes, which occurs in oblique rotations is responsible for this change. In the orthogonal solution the two axes maintain a 90° angle and the variables load as highly as possible on either of the axes. This requirement of a 90° right angle causes some of the variables to show only a moderate loading on a factor due to their location in the quadrant. Their location may be the central part of the quadrant defined by the axes. This would cause moderate loadings on both of the axes. The situation differs in an oblique rotation and the axes are not forced to maintain the 90° right angle. Due to the allowance of correlation

among the factors the axes create only a small acute angle. The point at which the axes pass through the quadrant may account for some of the changes among variables on the factors. The axes may pass more directly through the cluster of variables, when they are not restricted by the 90° right angle requirement. Table 4 presents the correlations among the

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INSERT TABLE 4 HERE

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factors. The moderate correlations suggest once again that "split brain" research may be useful in understanding the reliance one has on both hemispheres in connection with completing tasks represented on this measure. An orthogonal and oblique solution are not expected to yield identical results, yet in this case have produced results that appear a little unusual. The changes across the factors; therefore, are seen as related to placement of the axes as well as location of the variables in the quadrant. The solution options require the axes to represent the data in slightly different manners. It is further suggested that the tasks may require different abilities which do not yield separate (as in unique) factors. The tasks somehow rely on a combination of skills and result in factors which are "combinations".

Another aspect of the oblique solution which was also shown in the orthogonal solution is the high loadings of Variable 22 (Rhyme -- .57) and Variable 29 (Shapes -- .47). In the oblique solution they again appear highly related, yet are now positive and loading on Factor II instead of Factor I. Re-examination of the correlation matrix shows

the two variables to correlate highest with one another. Their relationship was seen as central to a particular modality of the brain. The change in sign and factor simply reflect the restrictions of the oblique and orthogonal solutions. Neither solution diminishes these two variables; and therefore, both solutions are seen as viable (in an intuitive sense) in representing the data. The use of subjective interpretation becomes important in choosing the most appropriate representation of the variables. The orthogonal solution is favored over the oblique solution.

Texts on factor analysis do not always agree on the interpretive methods used in an oblique solution. Some texts favor the use of the factor structure to derive the factors; whereas, other texts prefer the factor pattern be used when deriving the factors. The decision is left to the discretion of the researcher. The choice is not considered an arbitrary one; advantages and disadvantages are cited for both methods. In this analysis, due to the unusual differences in the oblique and orthogonal results, the factor pattern was also examined. It was hoped that new information would be gained and that it would be useful in the interpretation of the factors.

INSERT TABLE 5 HERE

An examination of the factor pattern yielded some interesting information that was not particularly helpful in any interpretive sense. Attention is drawn to the idea that the factor pattern summarizes the relative contribution of each factor to that variable for all of the

subjects (Gorsuch, 1974). The factors initially appear to be dissimilar from the previous factors of the orthogonal and oblique solutions. Major groups of variables appear together but on different factors and often appear to differ in intensity on the factor. The interesting relatedness of Variable 22 (Rhyme) and Variable 29 (Shapes) has also changed. The two variables appear to be significant contributors to different factors; whereas, they were contributors to the same factor in previous solutions. The factors derived from the factor pattern do not add clarity to the interpretation of the data; therefore, little emphasis was placed on them. The information was regarded as supporting the idea that the skills of this measure may require use of both hemispheres in the brain to complete the tasks. The five areas proposed by the instrument can be interpreted as requiring more than one modality to solve, as well as, some overlap in the areas proposed by the measure. Considering all three methods and their interpretations, the orthogonal solution and the factors derived from it appear to be the best representation for the data. The factors were easy to label and comprehend in a meaningful way. It is acknowledged that more research could supplement the interpretations and perhaps explain the results in a more unified and more concise fashion.

Following examination of the factor analysis performed on the data, a polycon analysis was done. This is a nonmetric scaling technique which uses "similarity distances" between the variables to spatially represent the structure of the data. The technique differs from factor analysis by assuming only ordinal measurement. This was seen as applicable to the data

generated by the KIDS assessment measure. (A general concern often brought forth in the social sciences is the level of measurement inherent in its measures.) Although the data may contain many dimensions, visual examination of the data is simplified by solutions which yield low dimensionality. The present data utilized the correlation coefficient to create and assign a new value to represent the relationships among the variables. It was also necessary to eliminate negative correlations by changing them in such a manner as to remove the negative sign while retaining the meaning of a negative correlation. The measures in this study are not "similarity measures" in the usual sense and do represent a linear transformation which confirms the interval scale properties of the correlations used in factor analysis. This is seen as appropriate because the purpose was to demonstrate the complementary nature of the multidimensional scaling solution to the factor analytic solution. If both solutions demonstrate similar "findings", one gains confidence in support of the underlying structure of the measure.

The linear transformation $s_{ij}=50\ (r_{ij} + 1)$ of the correlation coefficient r_{ij} was used to obtain similarity indices s_{ij}. They were non-negative on a scale from 0 to 100. This was done because the North Carolina polycon program does not accept negative numbers as similarity index values, and is justified because the results of the polycon analysis are invariant of any transformation (monotonic -- increasing) of the similarity index. The method is dependent only on the rank order of similarity.

The value of STRESS (2) was utilized to determine whether the data were best represented in two or three dimensions. Arbitrary constraints can again be applied as to "best" representation and "best" dimensionality. The two dimensional solution yielded a STRESS (2) value of .298; whereas, the three dimensional solution yielded a STRESS (2) value of .229. These values are within the range (.20 -- .40) regarded as "fair" by Rabinowitz (1975). This was considered adequate in determining the solution as information beyond three dimensions might complicate any interpretation as it is difficult to visualize more than three dimensions. The choice was seen as arbitrary but tied to the exploratory focus of the present analysis; and thus, representation of the data points was sought in the three dimensional solution.

INSERT FIGURES 1, 2, and 3 HERE

Although the smaller clusters contain a great deal of information, the major focus in interpreting the polycon analysis lies in the larger clusters of variables. The distances are considered first, followed by a discussion of the clusters appearing on the visual plot of the variables. A multiple regression analysis of the factor loadings and dimension scores was also utilized to study the data structure.

INSERT TABLE 6 HERE

The first cluster of variables includes body parts, visual same, count, association, colors, shapes, visual different, analogies, and visual closure. It is similar to Factor I and contains both the visual and identification elements of this factor. (Presented visually the tasks must be successfully identified by the subjects.) A difference is seen in the absence of a strong relatedness between rhyme and shapes which was present in the factor analytic solutions. One of the smaller clusters produces a small distance between the two variables; and yet the two techniques represent these highly related variables with some degree of difference. (A possibility may be the visual distinction of the tasks or the assumptions of each method.)

The second cluster includes visual same, association, size, visual different, figure ground, comparison, analogies, auditory closure, and count. This cluster also represents a similar factor seen the the factor analysis. These variables are visually presented and appear dependent on the use of a pattern to achieve successful identification of the stimuli. The distinction of the first two clusters is similar to the distinction between the first two factors. The manner in which identification skills are applied to stimuli; either to label the stimuli or by using an intermediate step to discern a pattern and apply it to the stimuli.

The third cluster includes visual closure, association, comparison, plurals, expression, analogies, and size. This cluster emphasizes the reliance on identification skills and strengthens the interpretation

that this skill underlies the data structure. The fourth cluster includes association, size, figure ground, analogies, memory, plurals, expression, and comparison. The use of a pattern is emphasized in this cluster. The fifth cluster includes auditory closure, time, analogies, size, count, and expression. Although the auditory component appears in this cluster, it is not as strong as the identification element.

Briefly summarizing the clusters of the polycon analysis, there appears to be confirmation of the elements derived in the factor analysis. The variables distinguish themselves along an identification dimension which is further refined by the use of visual and pattern discerning abilities. The fine motor factor is confirmed in the smaller cluster of variables 6 (Copy), 7 (Cut), 4(Color), and 5 (Trace). These variables require the use and control of fine muscles. The presentation method of the stimuli seem to account for the auditory, visual, and pattern qualities placed on the identification skills. A comparison of the factor analytic solution and the multidimensional scaling solution show them to be similar. Many fine distinctions and interpretations can be made which are dependent on the choice of method. The underlying dimensions in the data seem to be well represented by the factors derived in the orthogonal solution. The clusters derived in the polycon analysis support these factors as the underlying structure of the data.

Rabinowitz (1975) suggests that the difference between multidimensional scaling and factor analysis (the mathematical properties and restrictions

placed on the data) may account for the difference in results. The results obtained in these analyses do evidence similarity. Rabinowitz (1975) suggests that axes be extended through the clusters in a fashion similar to the rotational axes in orthogonal and oblique solutions. The major focus would be in determining an origin in multidimensional scaling where the origin is arbitrary. All multidimensional programs locate the origin and this can be used to "create" rotated solutions. (Caution remaining that the origin and distance not be interpreted as in factor analysis. Rabinowitz, 1975) The interpretation relates to the "relative" location of the points. Also the nature of the algorithm used in nonmetric multidimensional scaling is less sensitive to elements common to the entire set of items. The emphasis in nonmetric multidimensional scaling rests on those dimensions which lead to discrimination between items.

Rabinowitz (1975) further demonstrates the use of multidimensional scaling as confirmatory by using apriori dimensions discerned by the investigator or in this case discerned from the factor analysis.

> The basic numerical information we have at the end of multidimensional scaling procedures is a set of numbers which locate the object points on each of the (arbitrary) representational axes. Associated with each axis are as many numbers as there are points in the space. Think of axes as standard analytic variables. Suppose we performed an unstandardized multiple regression using as the independent variables the representational axes and using the dependent variable as the externally determined axis. . . . the linear combination of the representational axes which most closely corresponded with the external axis. For each representational axis we have a weight which reflects how important that axis is in predicting position on the external dimension.

b_1 $axis_1$ + b_2 $axis_2$ + constant + error

The b values are unstandardized regression coefficients. $Axis_1$ and $axis_2$ are variables representing the location of points on the representational axes. To determine the orientation of the axis, the slope is calculated by taking the ratio of b coefficients. (A simple procedure to construct an axis, once the b coefficients have been calculated, is to plot the point with the coordinates b_1 b_2 and draw the line determined by the point and the origin. This line is the appropriate axis.)

INSERT TABLES 7 AND 8 HERE

The axes shown in Figures 4 through 6 create dimensions which visually aid the interpretation of the data. The axes appear to confirm a visual identification dimension to characterize the data. The variables clustering on the axes and the differences on either end of the continuum may represent the presentation method of the stimuli. Rhyme, shapes, alphabet, and auditory same contain a visual component but are also auditory. Size, figure ground, balance, and body parts are variables requiring a greater degree of the visual element.

INSERT FIGURES 4, 5, and 6 HERE

The second axis appears to differentiate variables involving memory skills. One end of the continuum contains the variables of memory story,

memory numbers, and memory words. These reflect a memory component and the variable position can be interpreted as involving memory in recalling the correct use of the adjective presented. The other end of the continuum includes comparison, visual different, and memory (this variable presents objects for a time and the child must recall them in another stimulus field). This memory component may differ from others due to the visual presentation of the stimuli.

The factor analysis provided four factors as representative of the underlying structure of the data. The polycon analysis confirmed the factors as representative of the dimensions underlying the data. Although the results differ somewhat, the differences provided insight into the structure of the variables. Familiarity with factor analysis may provide the clarity that method seems to produce for the researcher. Additional interpretation of the present results is necessary to recover all the information obtained in this study. As an initial exploration of the data, the study demonstrates the use of multidimensional scaling techniques with this type of data. It also demonstrates their complementary nature in relation to factor analytic techniques in examining the underlying structure of data.

In summary, statements concerning recommendations about the two techniques are difficult to make explicit for all data is defined through subjective interpretation of analysis results. Both techniques demonstrated feasibility in describing the underlying structure of the data. The multidimensional scaling was used in a confirmatory fashion and supported much of the information derived through the factor analysis. The clarity

of both solutions appeared complementary in the sense that the multidimensional spatial configuration is an excellent visual aid to use in examining the data points. The multidimensional solution also provided insight into some of the variables. It suggests that additional information be sought to interpret the skills included on this measure. The strongest suggestion in regard to the use of the two approaches is that confirmation strengthens the validation procedure as well as the inferences that may eventually be drawn from the data set.

TABLE 1

EIGENVALUES AND COMMUNALITIES FOR THE FOUR FACTOR SOLUTION

Variable	Communality	Variable	Communality
1 Gross Motor	.408	19 Memory story	.314
2 Balance	.427	20 Auditory closure	.377
3 Body parts	.352	21 Auditory same	.347
4 Color	.386	22 Rhyme	.503
5 Trace	.330	23 Blending	----
6 Copy	.508	24 Counting	.431
7 Cut	.328	25 Colors	.458
8 Visual same	.530	26 Position	.379
9 Visual different	.447	27 Plurals	.335
10 Visual closure	.385	28 Alphabet	.424
11 Association	.544	29 Shapes	.504
12 Memory	.295	30 Expression	.326
13 Figure Ground	.715	31 Size	.613
14 Categories	.298	32 Time	.316
15 Sequence	.221	33 Comparison	.315
16 Letters	----	34 Analogies	.484
17 Memory numbers	.288	35 Opposites	.436
18 Memory words	.312	36 Numbers	.374

Eigenvalues of Factors		Percent of Variance	Cumulative Percent
Factor I	8.21	59.9	59.9
Factor II	3.71	27.1	86.9
Factor III	1.13	8.3	95.2
Factor IV	.65	4.8	100.0

TABLE 2

FOUR FACTOR ORTHOGONAL SOLUTION

Factor I		Factor II		Factor III		Factor IV	
Variable	Loading	Variable	Loading	Variable	Loading	Variable	Loading
13 Figure Ground	.83598	35 Opposites	.56718	25 Colors	.55744	6 Copy	.65183
31 Size	.75501	19 Memory Story	.47.58	28 Alphabet	.53059	7 Cut	.54191
11 Association	.70847	34 Analogies	.45747	29 Shapes	.51504	5 Trace	.47908
8 Visual same	.67212	21 Auditory same	.43283	17 Memory numbers	.50074	4 Color	.46166
2 Balance	.64167	22 Rhyme	.41887	24 Count	.48746	12 Memory	.34044
1 Gross Motor	.62753	14 Categories	.41819	18 Memory words	.45884		
3 Body parts	.50405	26 Position	.37996	26 Position	.43273		
20 Auditory closure	.48512	27 Plurals	.37760	36 Numbers	.42522		
9 Visual Different	.47181	33 Comparison	.37317	21 Auditory closure	.33429		
10 Visual closure	.46763	15 Sequence	.36527				
34 Analogies	.45359	9 Visual different	.35100				
27 Plurals	.43648	10 Visual closure	.34881				
30 Expression	.42444	30 Expression	.34185				
24 Count	.41785	36 Numbers	.33977				
4 Color	.40959	32 Time	.33834				
32 Time	.40348	12 Memory	.32793				
25 Colors	.35214						
33 Comparison	.35102						
22 Rhyme	-.47237						
29 Shapes	-.34999						
Label: Visual Identification		Label: Pattern Identification		Label: Visual and Auditory Memory		Label: Fine Motor Skill	

TABLE 3

FOUR FACTOR OBLIQUE SOLUTION

Factor I		Factor II	
Variable	Loading	Variable	Loading
34 Analogies	.65761	22 Rhyme	.57426
35 Opposites	.61792	29 Shapes	.47435
9 Visual different	.60104	13 Figure ground	-.81789
10 Visual closure	.56303	31 Size	-.69412
33 Comparison	.54360	11 Association	-.64347
31 Size	.52934	2 Balance	-.61621
20 Auditory closure	.52856	8 Visual same	-.60443
30 Expression	.53585	1 Gross motor	-.60286
19 Memory story	.52731	3 Body parts	-.42439
27 Plurals	.52509	20 Auditory closure	-.38634
26 Position	.52544	4 Color	-.37154
32 Time	.52454	10 Visual closure	-.37117
11 Association	.51149	27 Plurals	-.35755
8 Visual same	.49210	9 Visual different	-.35664
14 Categories	.48285	30 Expression	-.32339
12 Memory	.45448	34 Analogies	-.31988
36 Numbers	.45441	32 Time	-.30076
15 Sequence	.43082		
21 Auditory same	.42868		
25 Colors	.42211		
3 Body parts	.42073		
18 Memory words	.41097		

Factor III		Factor IV	
Variable	Loading	Variable	Loading
6 Copy	.68603	25 Colors	.64102
7 Cut	.56871	24 Count	.57474
5 Trace	.51219	26 Position	.55295
4 Color	.48057	18 Memory words	.53967
12 Memory	.44587	17 Memory numbers	.53035
36 Numbers	.40940	36 Numbers	.52691
14 Categories	.39899	28 Alphabet	.49654
9 Visual different	.38937	29 Shapes	.49453
21 Auditory same	.34844	34 Analogies	.45284
22 Rhyme	.34411	35 Opposites	.44494
15 Sequence	.33625	21 Auditory same	.42527
35 Opposites	.32628	3 Body parts	.40614
29 Shapes	.32111	9 Visual different	.39453
10 Auditory closure	.31302	19 Memory story	.38819
9 Visual same	.30355	20 Auditory closure	.38102
		33 Comparison	.35914
		32 Time	.35852
		30 Expression	.34046
		12 Memory	.33960
		14 Categories	.33361
		8 Visual same	.30849

TABLE 4

CORRELATION OF FACTORS IN OBLIQUE SOLUTION

	I	II	III	IV
Factor I	1.000	-.283	.394	.551
Factor II		1.000	.039	-.026
Factor III			1.000	.319
Factor IV				1.000

TABLE 5

OBLIQUE SOLUTION USING THE FACTOR PATTERN

Factor I

Variable	Loading
35 Opposites	.59597
34 Analogies	.57210
27 Plurals	.54464
19 Memory story	.49277
10 Visual closure	.43552
30 Expression	.43346
32 Time	.42597
33 Comparison	.42661
14 Categories	.40355
20 Auditory closure	.39958
9 Visual different	.38658
15 Sequence	.37306
31 Size	.37166
21 Auditory same	.35798
26 Position	.32963
22 Rhyme	.30511

Factor II

Variable	Loading
29 Shapes	.49278
28 Alphabet	.38230
21 Auditory same	.31188
13 Figure ground	-.75787
31 Size	-.58254
2 Balance	-.58229
1 Gross motor	-.58038
8 Visual same	-.55880
11 Association	-.56864
3 Body parts	-.38838
4 Color	-.38165
24 Count	-.30271

Factor III

Variable	Loading
6 Copy	.67217
7 Cut	.56327
5 Trace	.50439
4 Color	.49817
12 Memory	.30717

Factor IV

Variable	Loading
25 Colors	.62201
24 Count	.56849
17 Memory Numbers	.50837
28 Alphabet	.50035
18 Memory words	.46514
29 Shapes	.43559
26 Position	.36318
36 Numbers	.34258
3 Body parts	.31147

TABLE 6

DISTANCES OBTAINED FROM MULTIDIMENSIONAL SCALING SOLUTION

Cluster I	Variable	3	Body parts	
with	8	.269	Visual same	
	24	.419	Count	
	11	.488	Association	
	25	.550	Colors	
	9	.587	Visual different	
	34	.637	Analogies	
	10	.697	Visual closure	

Cluster II	Variable	8	Visual same	
with	10	.244	Association	
	31	.387	Size	
	9	.432	Visual different	
	10	.452	Visual Closure	
	13	.487	Figure ground	
	33	.502	Comparison	
	34	.547	Analogies	
	20	.594	Auditory closure	
	24	.596	Count	

Cluster III	Variable	10	Visual closure	
with	11	.379	Association	
	33	.422	Comparison	
	27	.465	Plurals	
	30	.519	Expression	
	34	.533	Analogies	
	31	.536	Size	

Cluster IV	Variable	11	Association	
with	31	.193	Size	
	13	.351	Figure ground	
	34	.527	Analogies	
	27	.557	Plurals	
	33	.591	Comparison	
	20	.545	Auditory closure	

Cluster IV	Variable	20	Auditory closure	
with	32	.313	Time	
	34	.381	Analogies	
	31	.454	Size	
	24	.488	Count	
	30	.578	Expression	
	11	.545	Association	
	13	.584	Figure ground	

TABLE 6 (Continued)

SMALLER CLUSTERS OF VARIABLES WERE SEEN IN THE FOLLOWING

Variable	2	Balance	
	13	.327	Figure ground
	11	.384	Association
	8	.486	Visual same
Variable	6	Copy	
	7	.456	Cut
Variable	12	Memory	
	14	.414	Categories
	33	.577	Comparison
Variable	13	Figure ground	
	31	.223	Size
	20	.584	Auditory closure
Variable	14	Categories	
	15	.452	Sequence
	35	.562	Opposites
Variable	26	Position	
	35	.370	Opposites
	36	.545	Numbers
Variable	4	Color	
	5	.396	Trace
Variable	9	Visual different	
	10	.286	Visual closure
	34	.465	Analogies
	11	.501	Association
	12	.576	Memory
Variable	17	Memory numbers	
	18	.467	Memory words
Variable	19	Memory story	
	35	.358	Opposites
	26	.551	Position
Variable	28	Alphabet	
	29	.297	Shapes
Variable	21	Auditory same	
	36	.483	Numbers
	35	.508	Opposites
	29	.562	Shapes
Variable	30	Expression	
	32	.365	Time
	34	.426	Analogies
	31	.559	Size
Variable	35	Opposites	
	36	.517	Numbers
Variable	25	Colors	
	26	.522	Position
	34	.565	Analogies
	33	.568	Comparison
Variable	27	Plurals	
	30	.347	Expression
	31	.570	Size
Variable	31	Size	
	34	.558	Analogies
	32	.573	Time
Variable	22	Rhyme	
	29	.438	Shapes
Variable	24	Count	
	25	.297	Colors
	34	.571	Analogies

TABLE 7

RATIO OF b COEFFICIENTS

Factor I R^2 = .938	
Dimension 3	-.17
Dimension 1	.35
Dimension 1	.35
Dimension 2	-.17
Dimension 2	-.17
Dimension 3	-.17

Factor II R^2 = .723	
Dimension 3	.28
Dimension 1	-.09
Dimension 1	-.09
Dimension 2	-.17
Dimension 2	-.17
Dimension 3	.28

Factor III R^2 = .830	
Dimension 3	-.21
Dimension 1	-.27
Dimension 1	-.27
Dimension 2	-.52
Dimension 2	-.52
Dimension 3	-.21

Factor IV R^2 = .870	
Dimension 3	.99
Dimension 1	.71
Dimension 1	.71
Dimension 2	.33
Dimension 2	.33
Dimension 3	.99

TABLE 8

COORDINATES OF EACH VARIABLE

Variable	Dimension I	Dimension II	Dimension III
1 Gross motor	.981	-.323	-.351
2 Balance	.983	-.218	-.285
3 Body parts	.389	-.014	-.521
4 Color	.796	.520	-.057
5 Trace	.491	.773	-.075
6 Copy	-.501	1.024	.416
7 Cut	-.206	1.248	.151
8 Visual same	.515	-.088	-.294
9 Visual different	.278	.004	.055
10 Visual closure	.504	-.142	.155
11 Association	.619	-.277	-.180
12 Memory	.061	.456	.330
13 Figure ground	.805	-.406	-.415
14 Categories	-.165	.277	.636
15 Sequence	-.002	-.058	.891
16 Letters	----	----	----
17 Memory numbers	-.894	-.070	-.536
18 Memory words	-.546	-.357	-.418
19 Memory story	-.422	-.425	.426
20 Auditory closure	.239	.605	-.394
21 Auditory same	-.833	.139	.406
22 Rhyme	-1.200	.595	.678
23 Blending	----	----	----
24 Counting	.047	-.227	-.637
25 Colors	-.155	-.080	-.476
26 Position	-.463	-.182	-.067
27 Plurals	.657	-.556	.301
28 Alphabet	-1.252	.509	-.039
29 Shapes	-1.169	.558	.242
30 Expression	.344	-.635	.174
31 Size	.644	-.451	-.260
32 Time	.179	-.758	-.128
33 Comparison	.125	-.017	.014
34 Analogies	.113	-.402	-.098
35 Opposites	-.399	-.096	.287
36 Numbers	-.562	.338	.059

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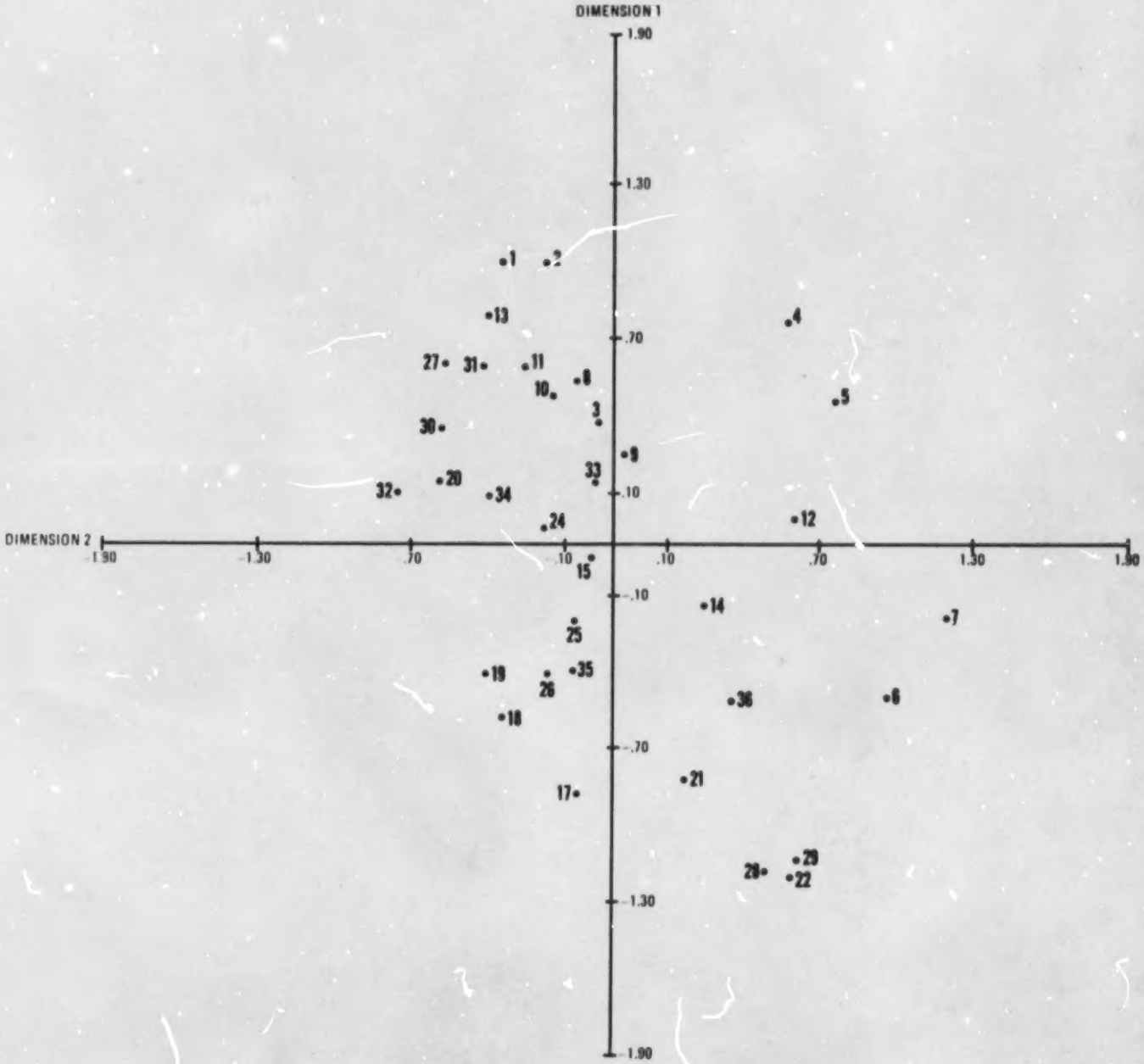
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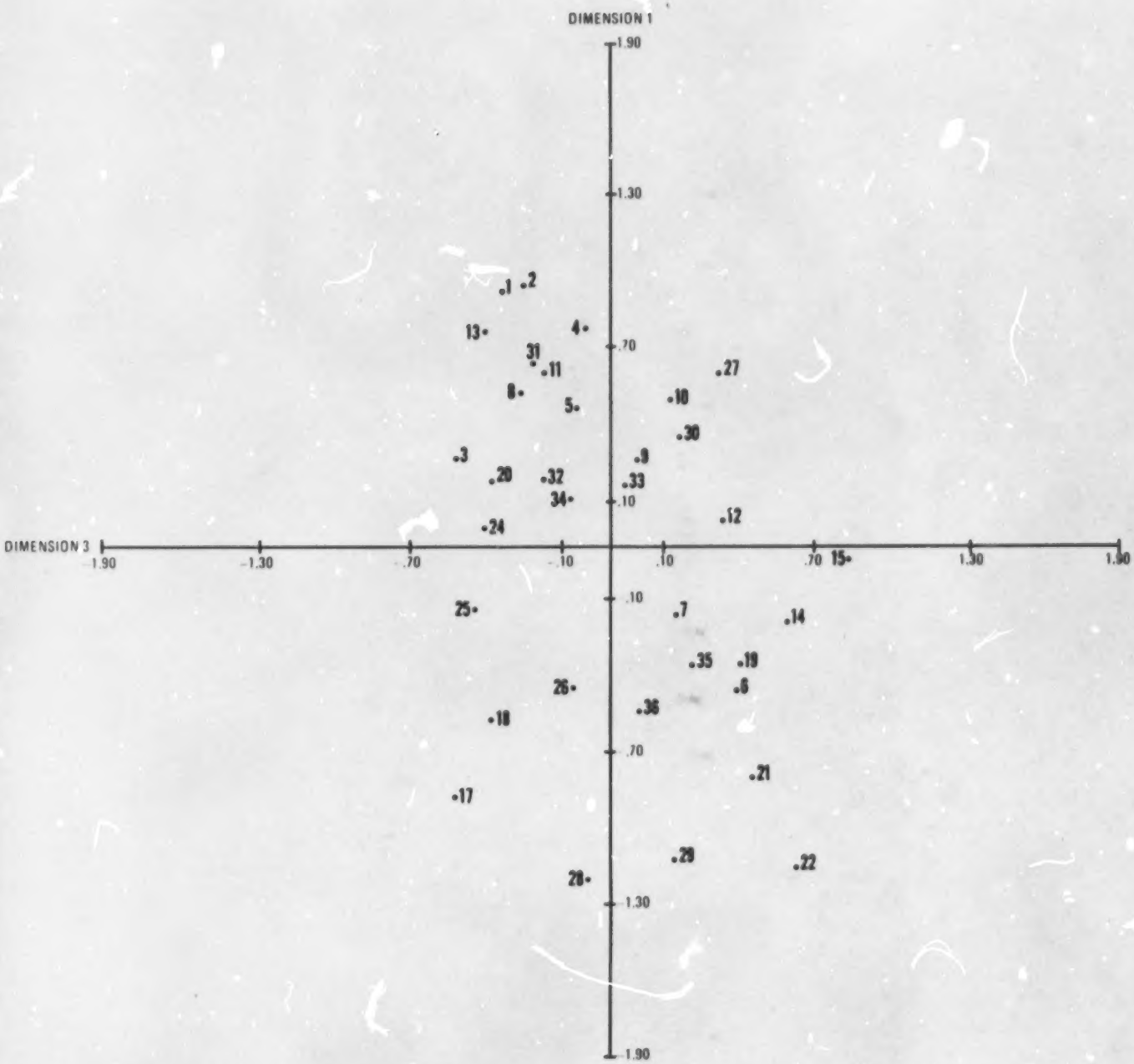
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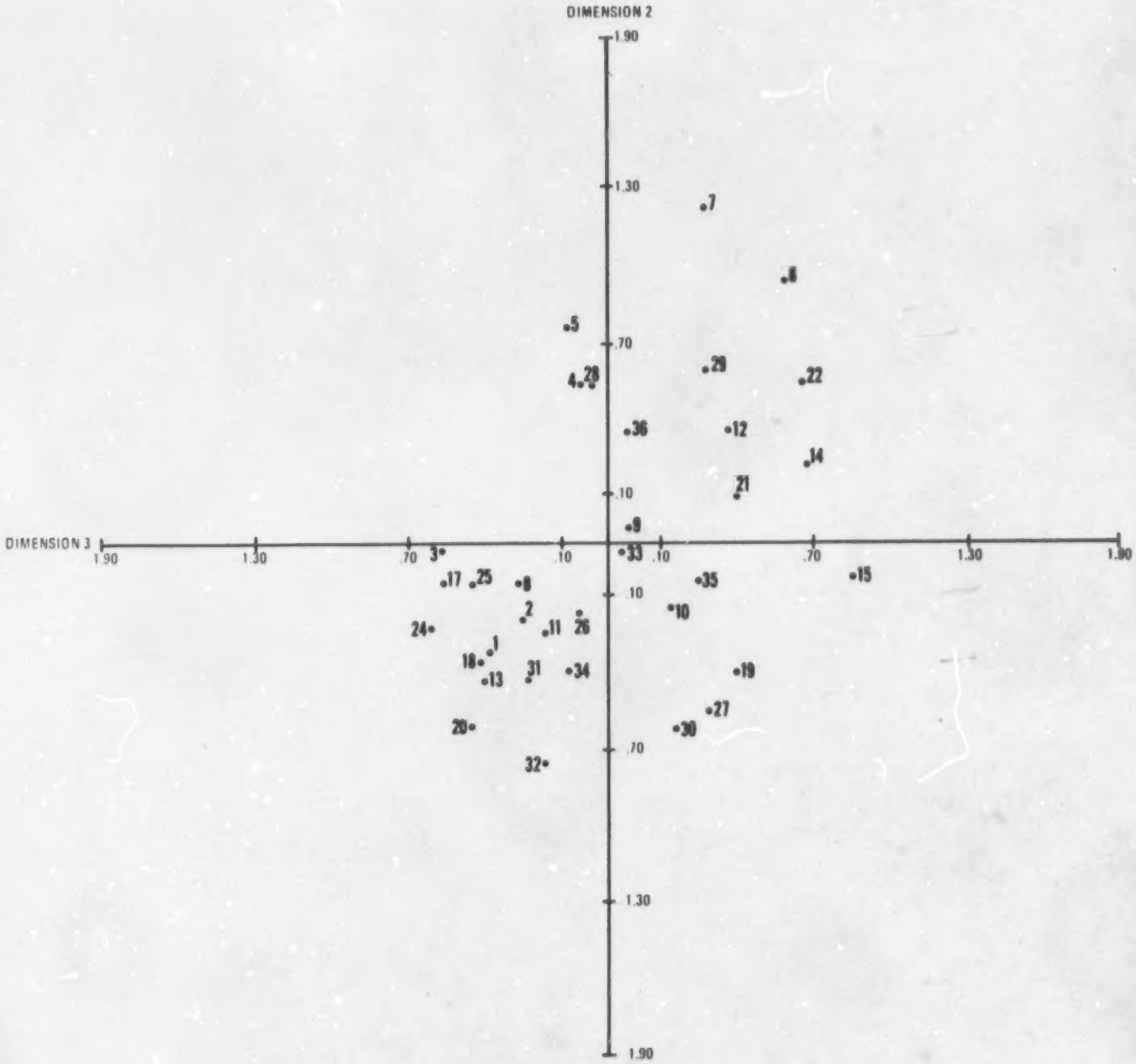
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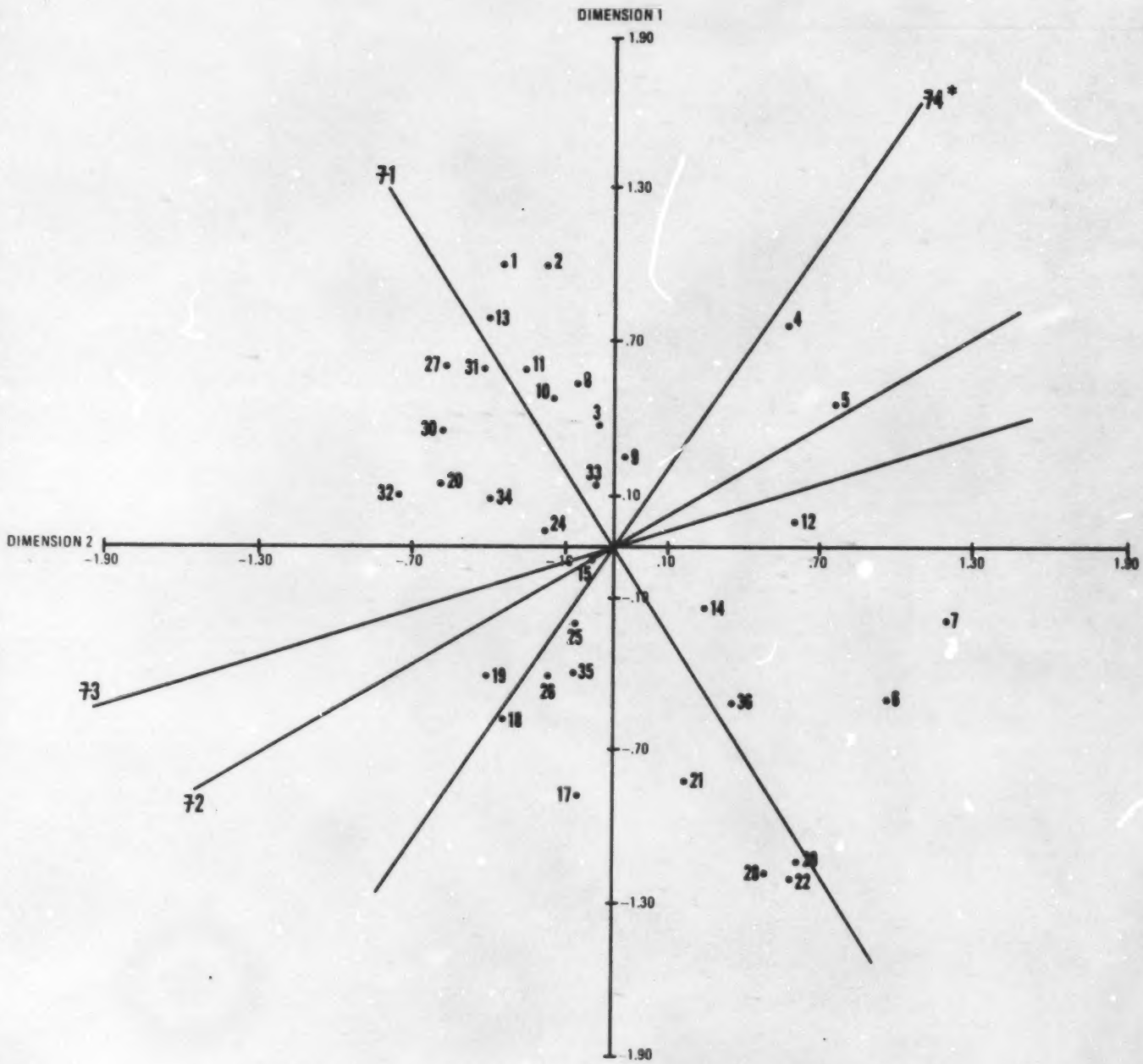
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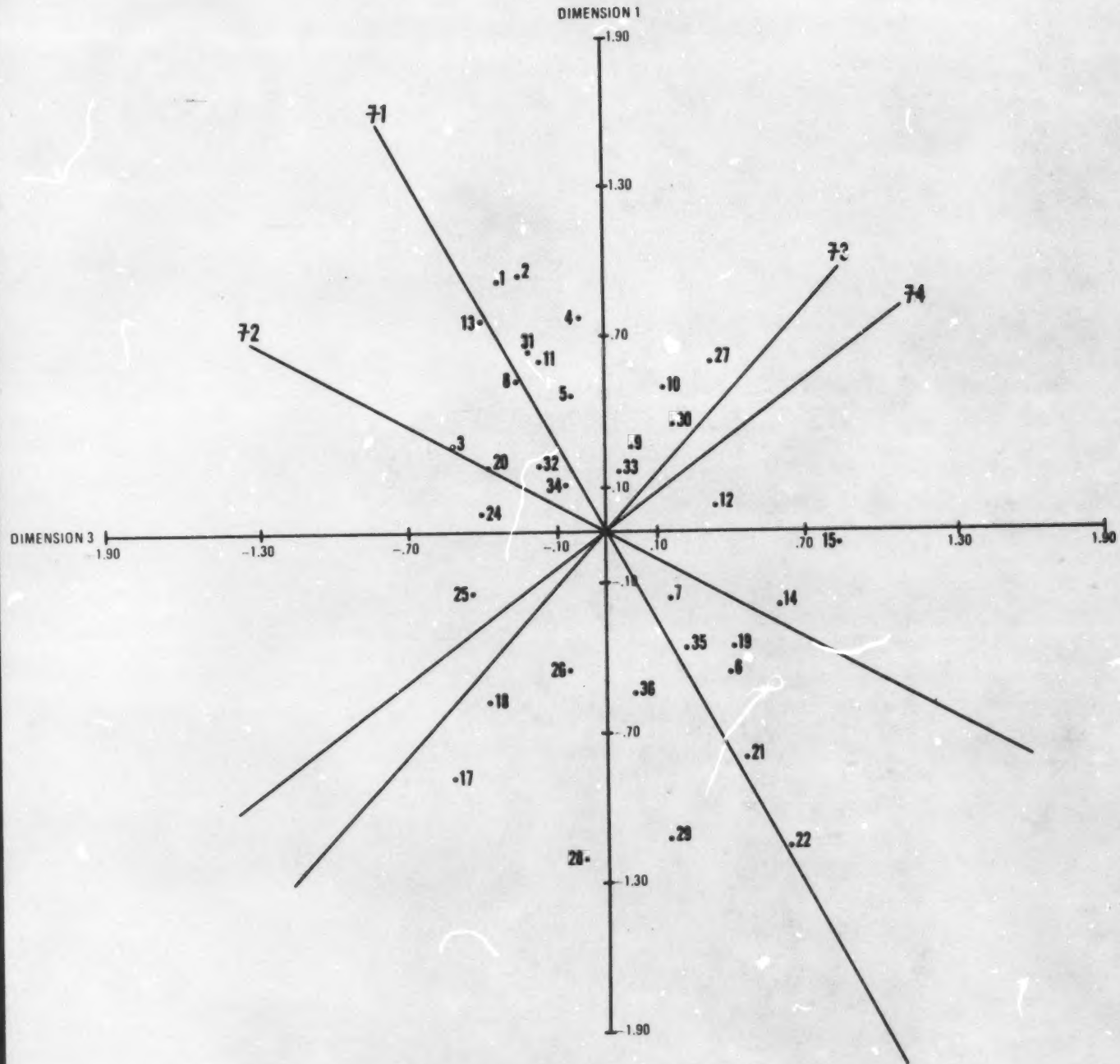
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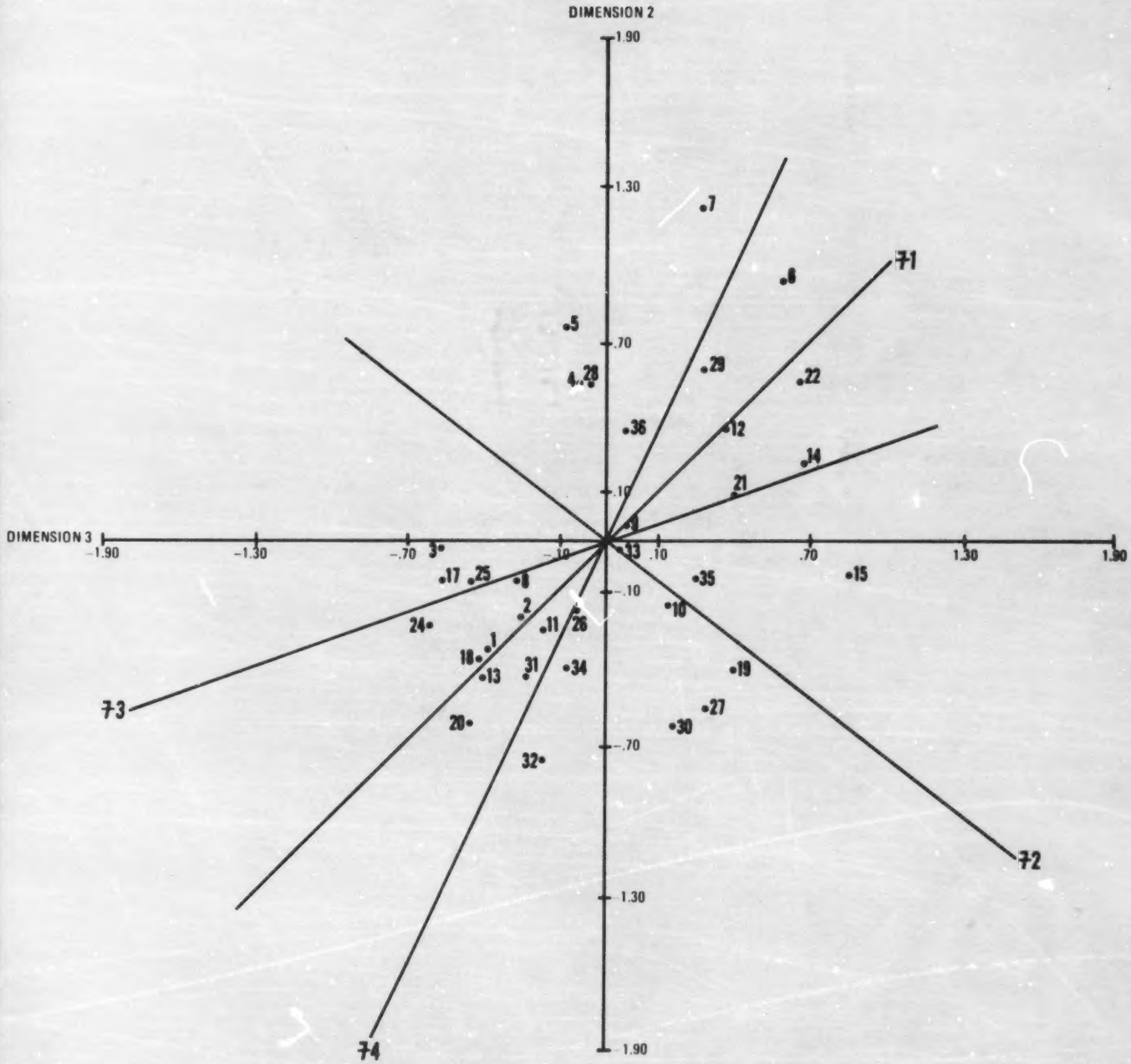
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